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(54) Optical head devices for generating and controlling a light beam

(57) An optical head device 10 for generating and controlling a light beam comprises a cylindrical supporting member 11, a semiconductor laser 12 contained in the supporting member 11 for generating a laser light beam and a hologram 16 operative to convert a spherical light wave diverging from one point into another spherical light wave converging to another point, the hologram 16 being attached to the cylindrical supporting member 11 so that the laser light beam generated by the semiconductor laser 12 passes through the hologram 16 in the direction along the axis of the cylindrical supporting member 11. A beam splitter 13 and a photo-sensor 18 may also be contained in the cylindrical supporting member 11 at positions between the semiconductor laser 12 and the hologram 16.

FIG. 2

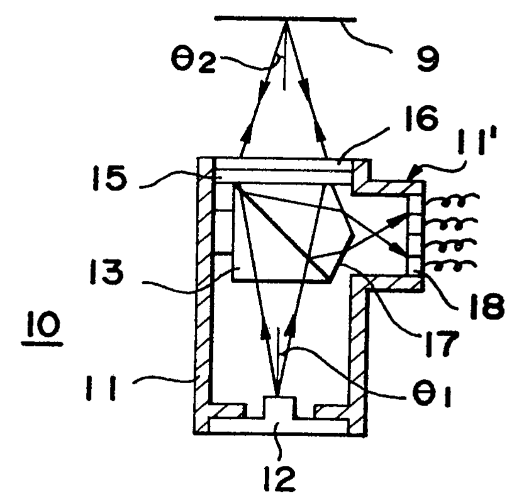

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FIG. 1

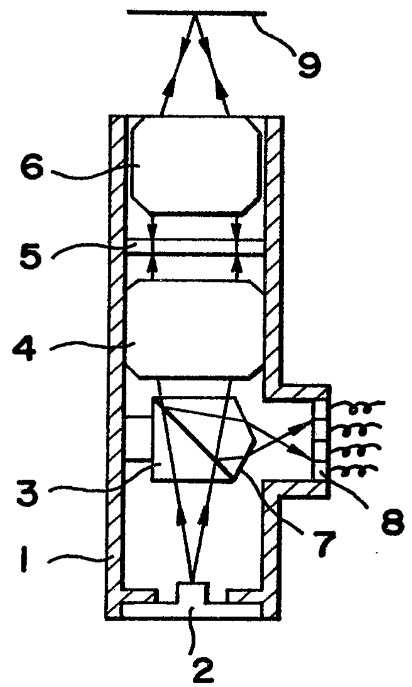


FIG. 2

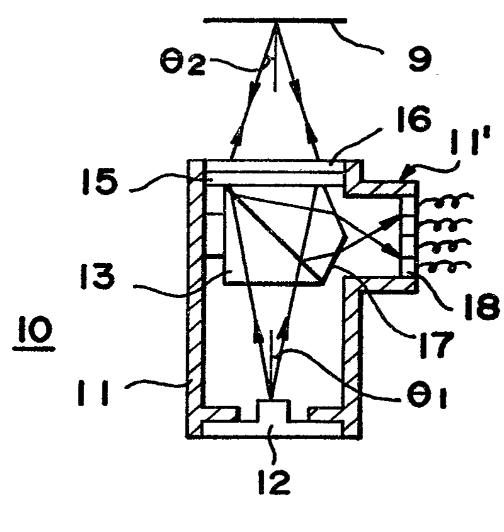


FIG. 3

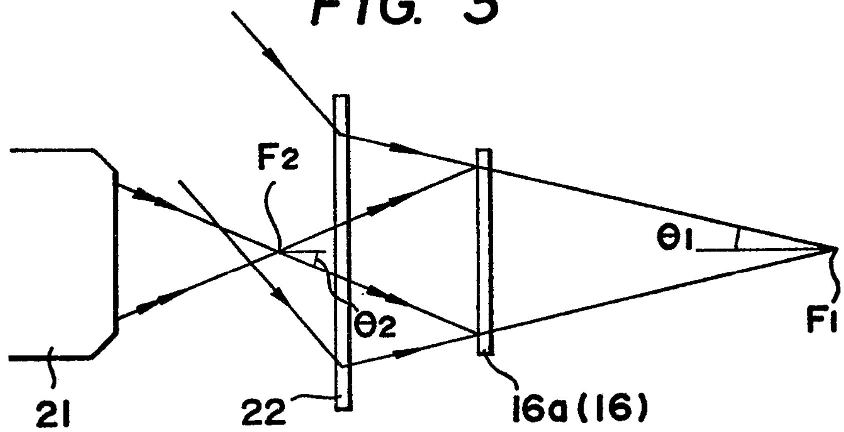


FIG. 4

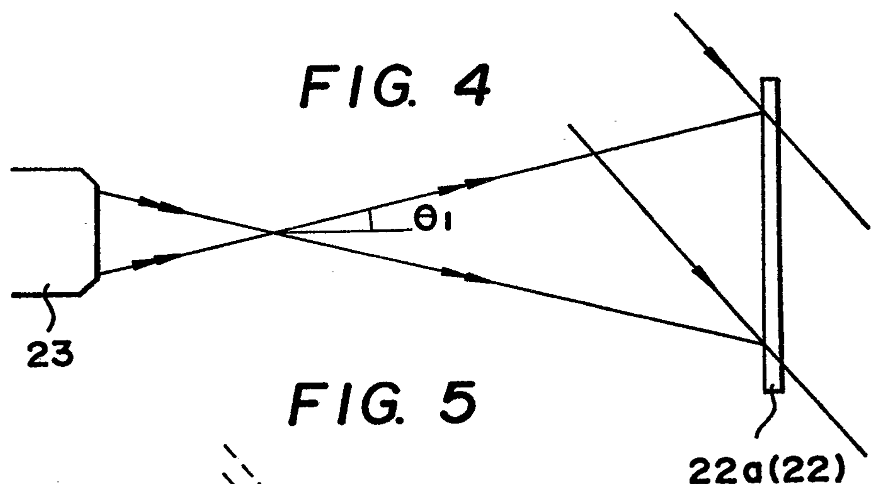


FIG. 5

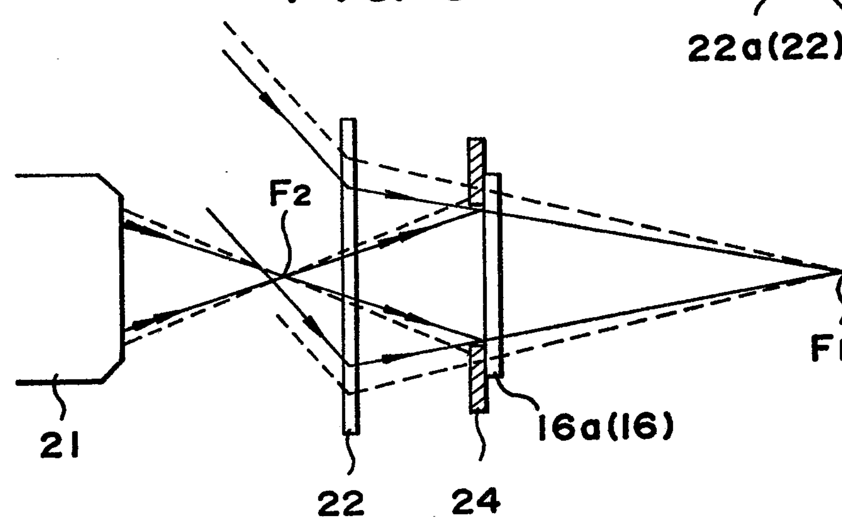


FIG. 6

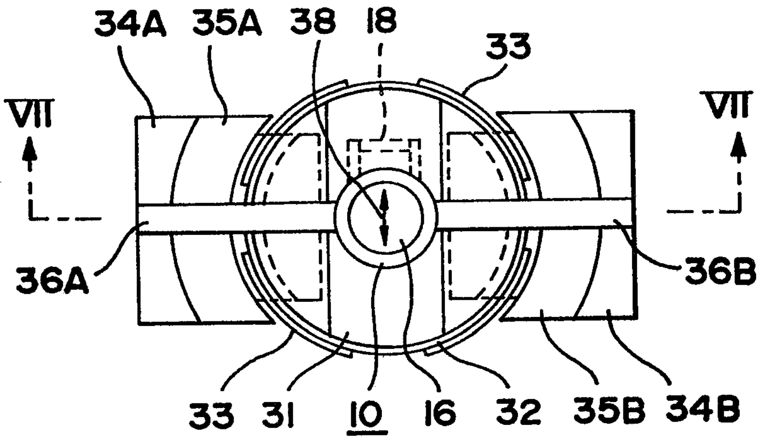


FIG. 7

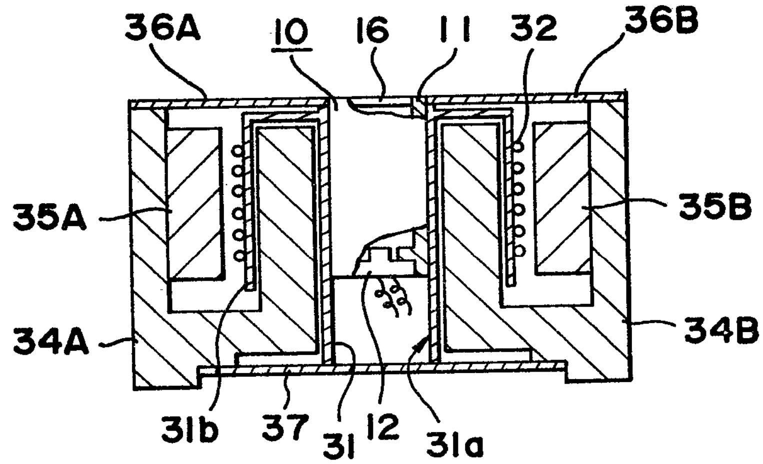


FIG. 8

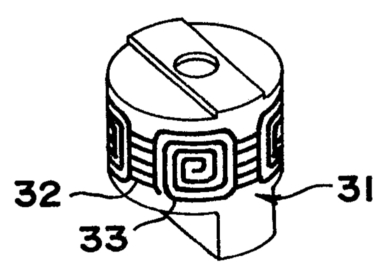


FIG. 9

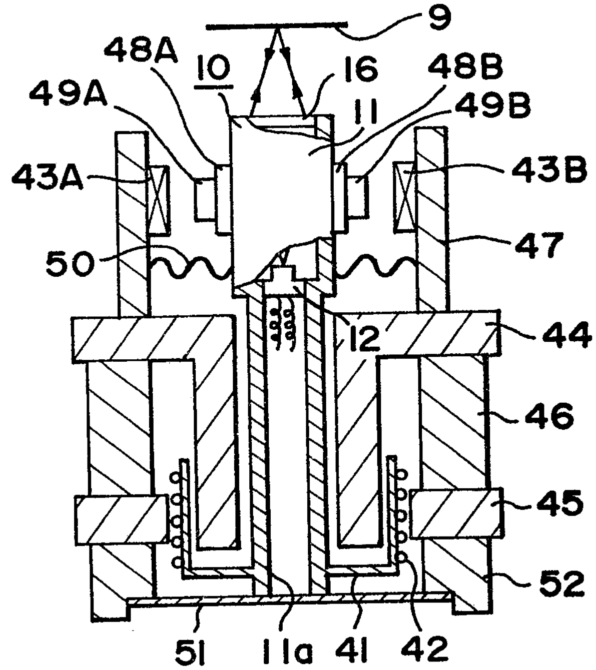


FIG. 10

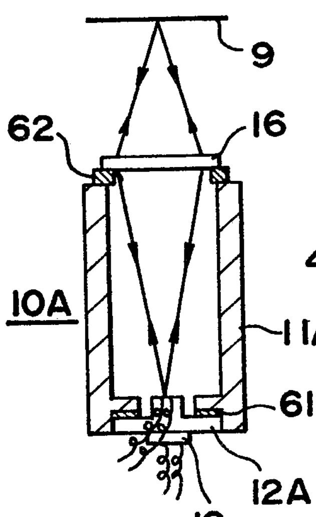
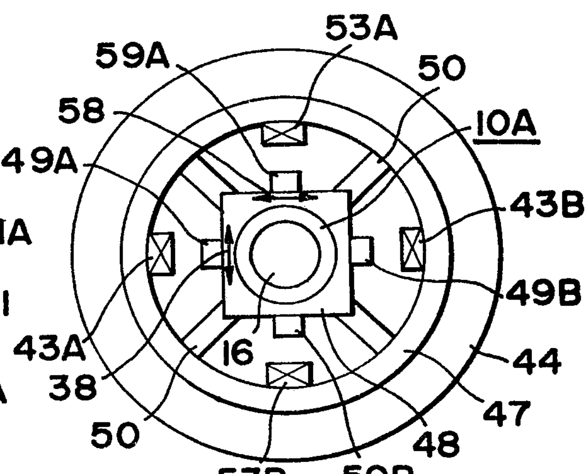


FIG. 11



SPECIFICATION

Optical head devices for generating and controlling a light beam

This invention relates to optical head devices for generating a controlling a light beam.

Embodiments of the invention can be used in an apparatus for optically reproducing information recorded on a record medium, such as, an optical disc player.

As an optical head device for use in an apparatus for reproducing information recorded on an optical record disc, it has been proposed to employ a compact optical pick-up device for guiding a light beam onto the optical record disc and receiving the light beam reflected from, or transmitted through the optical record disc, which optical pick-up device is generally referred to as being of the pencil type. In such a previously proposed optical pick-up device of the pencil type, a semiconductor laser for emitting a laser light beam, a polarized beam splitter, a collimator lens, a quarter-wave plate, an object lens and a photo-sensor are contained in a common cylindrical supporting member which is disposed so that the object lens faces the optical record disc.

However, since both the collimator lens and the object lens are contained in the common cylindrical supporting member, the cylindrical supporting member is relatively long in the axial direction and is also relatively heavy. In practice, it has been necessary for the collimator lens and the object lens are each to have a lengh of more than 4mm and a weight of more than 400mg in order adequately to perform their respective optical functions and, therefore, it has been almost impossible for the device, as a whole, to have a length of less than 35mm and a weight of less than 5g.

Consequently, it has been very difficult to achieve correct focus servo-control and tracking servo-control for the laser light beam directed onto the optical record disc from the object lens, by mounting the previously proposed optical pick-up device of the pencil type on a control device which moves the optical pick-up device in two perpendicular directions. Therefore, in the previously proposed optical pick-up device of the pencil type, the object lens is moved individually, that is, relative to the common cylindrical supporting member, in the direction of the axis thereof, for performing the focus servo-control, and the device as a whole is moved in the direction perpendicular to the axial direction of the common cylindrical member for performing the tracking servo-control. This arrangement is disadvantageous because the servo-control frequency band is not sufficiently broad, and the resistance to shocks is poor.

Although it is theoretically possible to use an object lens for directly converging the laser light beam emitted from the semiconductor laser into a very small point, thereby eliminating the need for the collimator lens, the object lens in such a case would be too long and heavy. Moreover, such an object lens would be formed by a plurality of lenses in the common cylindrical supporting member and, therefore, production of the optical pick-up device would be difficult.

According to the present invention there is provided an optical head device for generating and controlling a light beam, the device comprising:

a generally cylindrical supporting member;

a semiconductor laser contained in said supporting member for emitting a laser light beam; and

a hologram attached to said supporting member in such a manner that said laser light beam emitted by said semiconductor laser passes through said hologram in a direction along the axis of said cylindrical supporting member, said hologram being operative to convert a spherical light wave diverging from a point at said laser into another spherical light wave converging to another point outside said cylindrical supporting member.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a schematic sectional view showing an example of optical pick-up device of the pencil type according to the prior art;

Figure 2 is a schematic sectional view showing one embodiment of optical head device according to the invention;

Figures 3 to 5 are diagrammatic views to which reference will be made in explaining how a hologram is produced for use in an optical head device according to the invention;

Figure 6 is a plan view showing a controlled mounting movably supporting the optical head device of Figure 2;

Figure 7 is a sectional view taken along the line VII—VII in Figure 6;

Figure 8 is a perspective viewe of a part of the controlled mounting shown in Figures 6 and 7;

Figure 9 is a sectional view similar to that of Figure 7, but showing another example of the controlled mounting for movably supporting the optical head device of Figure 2;

Figure 10 is a schematic sectional view showing another embodiment of optical head device according to the invention; and

Figure 11 is a plan view of a controlled mounting for movably supporting the optical head device of Figure 10.

To facilitate understanding of the embodiments of the invention, an example of an optical pick-up device according to the prior art will first be explained with reference to Figure 1. This optical pick-up device is of the pencil type and comprises a cylindrical supporting member 1 in which there are suitably disposed a semi-conductor laser 2, a polarized beam splitter 3, a collimator lens 4, a quarter-wave plate 5, an object lens 6 and a photosensor 8. In order to detect errors in the focusing of a laser light beam generated by the semiconductor laser 2 and impinged on an optical

record disc 9 through the object lens 6, a prism 7 is provided integrally with the polarized beam splitter 3 at a surface of the latter from which the laser light beam emerges after being reflected from the record disc 9. The prism 7 is disposed so that a ridge line thereof lies in the direction perpendicular to the axis of the laser light beam passing therethrough, and the photosensor 8 is divided into four sections along spaced apart lines of separation which extend parallel to each other and to the ridge line of the prism 7.

This previously proposed optical pick-up device of the pencil type is undesirably long in the direction of the axis of the cylindrical supporting member 1, and also is undesirably heavy, because both the collimator lens 4 and the object lens 6 are contained in the common cylindrical supporting member 1.

A first preferred embodiment of optical head device 10 according to the invention will now be explained with reference to Figure 2. A cylindrical supporting member 11 contains a semiconductor laser 12, a polarized beam splitter 13, a quarter-wave plate 15, a hologram 16 and a photo-sensor 18. In this embodiment, a prism 17 is also shown to be provided on a surface of the polarized beam splitter 13 as an integral part thereof, and the photo-sensor 18 is divided into four sections in the same manner as the photo-sensor 8 mentioned above.

The hologram 16 used in optical head device 10 is operative to convert a spherical light wave diverging from one point into another spherical light wave converging to another point, that is, the hologram 16 acts as a lens for focusing a light beam. By way of example, and as shown in Figure 3, the hologram 16 can be obtained by placing an auxiliary hologram 22 and a thin film 16a of dichromate gelatin which is to become the hologram 16, in a light path passing through an object lens 21. A converging spherical light wave having a numerical aperture sin θ_1 is brought by the auxiliary hologram 22 to interfere with a diverging spherical light wave of numerical aperture sin θ_2 brought by the object lens 21 onto thin film 16a. In this way the thin film 16a is turned into the hologram 16 which can act as a lens for converting a spherical light wave diverging from a point F_1 with the numerical aperture sin θ_1 into a spherical light wave converging to a point F_2 with the numerical aperture sin θ_2. Moreover, as shown in Figure 4, the auxiliary hologram 22 can be obtained by placing a thin film 22a in a light path passing through an object lens 23, and causing a converging spherical light wave of numerical aperture sin θ_1 to be brought by the object lens 23 into interference with a plane light wave on the thin film 22a.

Since the hologram 16 can act generally as a lens for converging a spherical light wave diverging from one point into another spherical light wave converging to another point, it is possible to use the hologram 16 to focus the laser light beam diverging from the semiconductor laser 12 onto the record disc 9 as shown in Figure 2 and to read the information recorded thereon without using the collimator and the object lenses of the prior art.

The optical head device 10 according to the invention is substantially miniaturized in size and very much reduced in weight. For example, when the radius of an equivalent lens formed by the hologram 16 and of numerical aperture sin θ_2 are 2mm and 0.5, respectively, the hologram 16 can be placed at a distance of 3.46mm from the recorded surface of the record disc 9. In that case, if the laser light beam focused by the hologram 16 is directed through the body of the record disc 9 to the recorded surface of the record disc 9 for reading the information recorded thereon, and if the thickness of the body of the record disc 9 is 1.2mm., the distance between the hologram 16 and the record disc 9 is 2.26mm. Moreover, if the above mentioned numerical aperture sin θ_1 is arranged to be 0.15, the distance between the semiconductor laser 12 and the hologram 16 is only 13.18mm, from which is follows that the optical head device 10 is, as a whole, substantially miniaturized, and it may, for example, be less than 15mm. Moreover, in a case where the hologram 16 is formed with an area of $9mm^2$ and a thickness of 1.2mm, its weight is about 270mg. Since the polarized beam splitter 13 can be formed with its body measuring $5mm^3$ to weigh approximately 340mg, the semiconductor laser 12 weighs approximately 500mg and the photo-sensor 18 weighs approximately 400mg, and it is possible for the cylindrical supporting member 11 to weigh less than 1g by being made, for example, of aluminium, the optical head device 10, as a whole, can be made to weigh less than 3g.

Incidentally, although it is possible to obtain only a circular aperture when using an ordinary lens made of glass, the aperture of the equivalent lens formed by the hologram 16 can be made to have various shapes, for example, elliptical, square, rectangular or other desirable shapes, by providing a mask 24 of the desired shape, as shown in Figure 5. In the case of the elliptical or rectangular aperture, the amount of laser light beam passing therethrough is increased when the laser light beam is emitted with anisotropy from the semiconductor laser 12, so that the utlization efficiency of the laser light beam is improved. By reason of such increase in utilization efficiency, the emitting power of the semiconductor laser 12 can be reduced so that the useful life of the semiconductor laser 12 is extended.

Since the optical head device 10 is substantially miniaturized and greatly reduced in weight, it is possible to achieve the focus servo-control and the tracking servo-control of the laser light beam directed onto the record disc 9 by a controlled mounting of the optical head device 10 which moves the latter, as a unit, in two perpendicular directions, while ensuring that the frequency band of the servo-control will be sufficiently broad and that there will be superior

resistance to shocks. One example of a controlled mounting for moving the optical head device 10 in two perpendicular directions is shown in Figures 6 and 7. In this example, a bobbin 31 having coaxial inner and outer cylindrical portions 31a and 31b is provided for mounting of the optical head device 10 in its inner cylindrical portion 31a. A first moving coil 32 for the focus servo-control and a second moving coil 33 for the tracking servo-control are fixed on the outside of the bobbin 31, as also shown in Figure 8. A pair of magnetic yokes 34A and 34B, to which a pair of magnets 35A and 35B, respectively, are attached, are disposed opposite to each other with the bobbin 31 therebetween. The top end of the inner cylindrical portion 31a of the bobbin 31 and the top end of cylindrical supporting member 11 of the optical head device 10 are movably supported or suspended through a pair of resiliently flexible elements or dampers 36A and 36B from the upper ends of the magnetic yokes 34A and 34B. The bottom end of the inner cylindrical portion 31a of the bobbin 31 is also movably supported through a resiliently flexible element or damper 37 from the bottom ends of the magnetic yokes 34A and 34B so that the optical head device 10 can move with the bobbin 31 both in the direction of the axis of the bobbin 31, that is, in the up-and-down direction, and in the direction at right angles to such axis, as indicated by the double-headed arrow 38 in Figure 6.

As mentioned above, the length of the optical head device 10 can be less than 15mm and, therefore, it is possible to form the bobbin 31 to have an outer diameter of about 22mm. In such a case, for example, the magnetic yokes 34A and 34B can be dimensioned, in the direction from top to bottom, to be about 25mm and, in the lateral direction, to be about 36mm. Further, as also earlier noted, the weight of the optical head device 10 can be less than 3g and, therefore, it is possible to obtain a focus servo-control frequency band extended to, for example, 1.5 kHz, and a tracking servo-control frequency band extended, for example, to 3 kHz. These servo-control frequency bands are sufficiently broad for the respective servo-controls.

Figure 9 shows another example of a controlled mounting for supporting the optical head device 10 to move in two perpendicular directions. The optical head device 10 is shown to be inserted into the magnetic assembly comprising the magnetic yokes 34A and 34B and the magnets 35A and 35B in the embodiment shown in Figures 6 and 7. However, in the example of Figure 9, the cylindrical supporting member 11 of the optical head device 10 is elongated or extended downward, as at 11a, and a bobbin 41 is formed integrally with such elongated portion 11a of the cylindrical supporting member 11. A moving coil 42 for the focus servo control is wound on the bobbin 41 and a magnetic assembly comprising magnetic yokes 44 and 45 and a magnetic 46 therebetween is provided around the elongated portion 11a of the cylindrical supporting member 11. A ring-shaped member 47 extends upwardly from the magnetic yoke 44 at the top of the latter, and a pair of stationary coils 43A and 43B for the tracking servo-control are attached to the inner surface of the ring-shaped member 47 at diametrically opposed locations on the latter. Further, a pair of magnets 49A and 49B are attached through holders 48A and 48B to the outside of the supporting member 11 of the optical head device 10 at positions facing the stationary coils 43A and 43B, respectively. The cylindrical supporting member 11 is movably supported through a damper 50 by the ring-shaped member 47 and through a damper 51 by another ring-shaped member 52 connected to the magnetic yoke 45 at the bottom end of the latter.

Figure 10 shows another embodiment of an optical head device 10A according to the invention, and in which the polarized beam splitter 13 and the quarter-wave plate 15 of Figure 2 are not used and a semiconductor laser 12A is operative to function as a photo-detector as well as the source of the laser light beam. The hologram 16 is operative so as very positively to return the reflected laser light beam from the optical record disc 9 to the semiconductor 12A, and the embodiment of Figure 10 makes the most of this characteristic of the hologram 16. With this embodiment, it is not necessary to provide any projecting portion on the outside of the cylindrical supporting member 11A, as distinguished from the embodiment of Figure 2 in which the member 11 has a lateral projecting portion 11′ to house the photo-sensor 18. Therefore, the cylindrical supporting member 11A can be made symmetrical in all directions about its longitudinal axis to permit achievement of an additional servo-control for time base correction of the reproduced signal obtained from the information read by the laser light beam in addition to the focus and tracking servo-controls. For achieving the foregoing, there is provided a three-dimensional controlled mounting which can move the cylindrical supporting member 11A mounted thereon in three different directions perpendicular to one another, for example, as shown in Figure 11.

More particularly, the optical head device 10A of Figure 10 is shown in Figure 11 to be mounted on a magnetic assembly which is substantially the same as that described above with reference to Figure 9. Thus, the magnetic assembly of Figure 11 is shown to include a ring-shaped member 47 and stationary coils 43A and 43B for the tracking servo-control attached to the inner surface of the ring-shaped member 47 at locations which are diametrically opposite to each other in a first direction. However, in Figure 11, another pair of stationary coils 53A and 53B for the time base correction servo-control are also attached to the inner surface of the ring-shaped member 47 so as to be diametrically opposite to each other in a second direction perpendicular to the first direction. A rectangular holder 48 is mounted on

the outside of the optical head device 10A, and magnets 49A and 49B are attached to the surface of the rectangular holder 48 which are opposite to the stationary coils 43A and 43B, respectively. Another pair of magnets 59A and 59B are attached to the surface of the rectangular holder 48 which are opposite to the stationary coils 53A and 53B, respectively. Thus, the optical head device 10A can be moved in the directions perpendicular to one another indicated by the double-headed arrows 38 and 58 in Figure 11 for correcting tracking errors and for correcting time base errors, respectively, by the selective energizing of the coils 43A and 43B and the coils 53A and 53B, respectively. The controlled mounting for the optical head device 10A further includes an arrangement (not shown) for effecting movement of the supporting member 11A in the direction of its longitudinal axis so as to correct focusing errors, for example, as formed by the coil 42 and the magnet 45 of Figure 9. Therefore, the optical head device 10A can be moved in all three directions perpendicular to each other for effecting tracking, time base and focusing servo-control.

In the optical head device 10A, a piezoelectric element 61 is provided between the bottom of the cylindrical supporting member 11A and the semiconductor laser 12A, as shown in Figure 10. A voltage for wobbling operation is suitably supplied to the piezoelectric element 61 for vibrating it and thereby wobbling the semiconductor laser 12A in the direction along the axis of the laser light beam emitted by the laser 12A so that errors in the focus servo-control can be detected in a known manner.

Alternatively, in place of the piezoelectric element 61, a rear monitor photodetector 19 may be provided for the semiconductor laser 12A to detect errors in the focus servo-control. Moreover, another piezoelectric element 62 may be provided between the top end of the cylindrical supporting member 11A and the hologram 16, as shown in Figure 10. A voltage is suitably supplied to the piezoelectric element 62 for vibrating it and therefore wobbling the hologram 16 in the direction perpendicular to the axis of the laser light beam emitted by the semiconductor laser 12A. Such wobbling of the hologram 16 is employed, in a known manner, in order to detect errors in the tracking servo-control. More particularly, errors in the tracking servo-control may be detected by a photo-sensor (not shown) provided for receiving the laser light beam after it has passed the wobbled hologram 16 and been reflected at the optical record disc 9.

Claims

1. An optical head device for generating and controlling a light beam, the device comprising:

a generally cylindrical supporting member;

a semiconductor laser contained in said supporting member for emitting a laser light beam; and

a hologram attached to said supporting member in such a manner that said laser light beam emitted by said semiconductor laser passes through said hologram in a direction along the axis of said cylindrical supporting member, said hologram being operative to convert a spherical light wave diverging from a point at said laser into another spherical light wave converging to another point outside said cylindrical supporting member.

2. An optical head device according to claim 1 further comprising a beam splitter means contained in said supporting member at a position between said semiconductor laser and said hologram, and a photo-sensor attached to said supporting member to receive a laser light beam split by said beam splitter.

3. An optical head device according to claim 2 further comprising mounting means for holding said cylindrical supporting member, and driving means for electromagnetically moving said mounting means in at least two different directions.

4. An optical head device according to claim 3 wherein said driving means electromagnetically moves said mounting means in both a first direction along said axis of said cylindrical supporting member and a second direction perpendicular to said first direction.

5. An optical head device according to claim 1 wherein said semiconductor laser is attached through a first piezoelectric element to said cylindrical supporting member and said hologram is attached through a second piezoelectric element to said cylindrical supporting member.

6. An optical head device according to claim 5 wherein said laser light beam emerges from said supporting member through said hologram and is reflected at the outside of said supporting member so as to re-enter said supporting member through said halogram, and said semiconductor laser also receives said laser light beam which re-enters the supporting member.

7. An optical head device according to claim 1 wherein said laser light beam emerges from said supporting member through said hologram and is reflected at the outside of said supporting member so as to re-enter said supporting member through said hologram and be directed by said hologram against said semiconductor laser.

8. An optical head device according to claim 7 further comprising mounting means for holding said cylindrical supporting member, and driving means for electromagnetically moving said mounting means in the direction of said axis of the cylindrical supporting member for focus servo-control and in orthogonally related directions which are perpendicular to said axis for tracking and time base servo-controls.

9. An optical head device for generating and controlling a light beam, the device being substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

10. An optical head device for generating and controlling a light beam, the device being

substantially as hereinbefore described with reference to Figures 2 and 6 to 8 of the accompanying drawings.

11. An optical head device for generating and controlling a light beam, the device being substantially as hereinbefore described with reference to Figures 2 and 9 of the accompanying drawings.

12. An optical head device for generating and controlling a light beam the device being substantially as hereinbefore described with reference to Figure 10 of the accompanying drawings.

13. An optical head device for generating and controlling a light beam, the device being substantially as hereinbefore described with reference to Figures 10 and 11 of the accompanying drawings.

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